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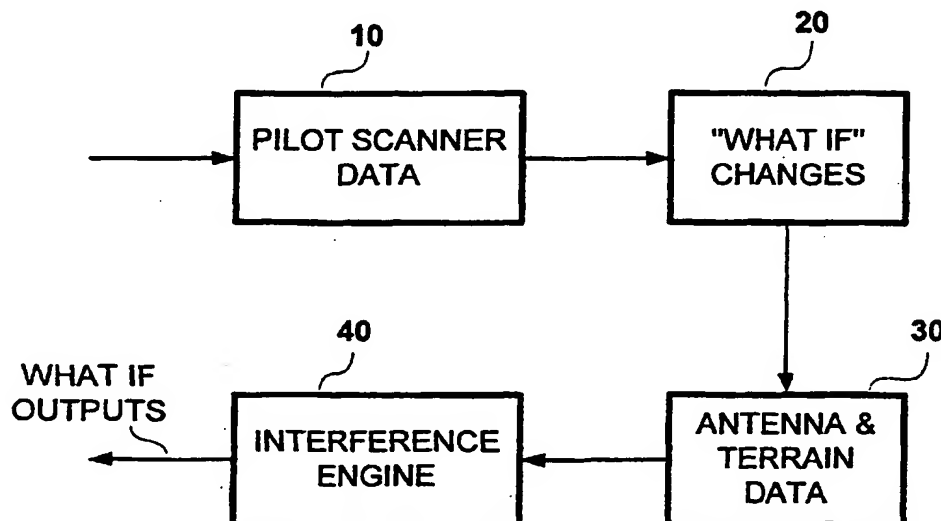
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(54) Title: **WIRELESS TELEPHONE NETWORK OPTIMIZATION**

(57) Abstract: A wireless network can be easily optimized utilizing processes according to the present invention. A simulation environment allows a network engineer to vary parameters (e.g., antenna height, tilt, and power) of a virtual model of the wireless network and observe how the changes affect coverage. Algorithms also enable hand off timing parameters for sectors in a wireless network to be optimized. One algorithm analyzes measured data regarding network coverage and regional terrain to arrive at a report containing recommended values for window size parameters (code division systems) or timing advance parameters (time division systems). Another algorithm analyzes measured data regarding network coverage to arrive at a report containing recommended neighbour list for each sector in the network.

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1 Title: **WIRELESS TELEPHONE NETWORK OPTIMIZATION**

2
3 **BACKGROUND OF THE INVENTION**

4 **1. Field of the Invention**

5 The present invention is directed to the art of wireless telephone networks. More
6 particularly, the present invention is directed to optimizing parameters of radio base
7 stations in a wireless telephone network.

8 **2. Background Information**

9 Cellular and PCS telephone services have enjoyed explosive growth over the last
10 ten years. There is no reason to believe that this growth will not continue for some time.
11 This continued growth creates a great demand for the infrastructure that supports these
12 services. As more and more people begin to use wireless telephones, more and more fixed
13 location base stations must be installed across the landscape to handle the rising demand
14 for wireless traffic.

15 Each wireless telephone base station has a plurality of transceivers, each connected
16 to a respective antenna. The electromagnetic radiation pattern of each of these antennas
17 defines the coverage area of a "sector." Each sector in the wireless network has some
18 degree of overlap with one or more nearby sectors, and in the aggregate, the coverage
19 areas of all the sectors in the network define coverage area of the network as a whole.

20 One difficulty in establishing a network of base stations is that the aggregate
21 coverage provided by the sectors is not perfect. It may have weak spots, or self-
22 interference spots, where wireless telephony functions at a substandard level or it may
23 even have dead spots where no wireless calls can function at all. Such problems can be
24 rectified by optimizing the sectors to attempt to cover the weak and/or dead spots in
25 wireless coverage. Coverage optimization may be accomplished by varying a number of
26 parameters for each sector. One parameter to vary is the azimuth angle at which the
27 antenna for the sector is pointed. Other parameters to vary are the antenna height (moving
28 the antenna higher or lower on its tower, host building, or other supporting structure), the
29 angle of tilt of the antenna (useful in uneven terrain locations), and the amount of power
30 radiated by the antenna. Additionally, the option is also available to substitute a different

1 type of antenna (different model or different manufacturer entirely) in order to obtain
2 better coverage results.

3 This optimization process is laborious and time consuming. Each time a network
4 engineer wants to change four of the five above-identified parameters of a sector (azimuth,
5 height, tilt, antenna type), someone has to climb up a tower (or other support structure)
6 and physically make an adjustment to the antenna. Only power changes can be made
7 without a need to get at the antenna. Once a parameter has been varied, a fresh set of
8 signal strength measurements must be made by physically driving around the relevant
9 terrain with a measurement device to map out how the parameter change has affected
10 coverage. After analyzing the measurements, another parameter (perhaps for a different
11 sector) can then be varied. This iterative process of vary-measure-vary-measure is
12 repeated over and over again until an optimum result is obtained. It takes a long time and
13 relies upon highly skilled workers to accomplish.

14 Thus, what is needed is a labor-saving and time-efficient way to develop optimum
15 coverage-related parameters for sectors of a wireless network.

16 A wireless telephone often communicates via a number of sectors in succession in
17 the course of a single telephone call via a process called hand-off. In simple terms, one
18 sector will transfer to a neighboring sector the responsibility for handling the wireless
19 telephone call. A hand off may be necessitated because the wireless telephone unit is
20 portable and has moved out of the effective range of the sector that had been heretofore
21 handling the call, or it may be necessitated due to high demand for the limited number of
22 channels that the sector can provide. This is (ideally) done in a seamless manner such that
23 the user of the telephone never notices any discontinuity in service.

24 In order for call hand offs between sectors to be performed effectively, a number of
25 parameters of the hardware supporting each sector need to be optimized. One parameter is
26 called a "neighbor list." Each sector has a neighbor list, which is a ranked listing of
27 neighboring sectors to which hand offs may most appropriately be made. The ranking of
28 members in a neighbor list is an important factor in enabling effective hand offs.
29 However, prior art practice is for a network engineer to simply make an educated guess as
30 to which neighboring sectors should be included as members of the neighbor list of a
31 given sector, as well as how to rank the members of the list by importance. Prior art

1 practice does not include a rigorous analysis of how members of a neighbor list should be
2 ranked, or even which neighboring sectors should be included as members of the list.

3 Another parameter relevant to hand off effectiveness in CDMA wireless networks
4 is "window size." Window size is a parameter that is set for each sector uniquely. This
5 parameter tells a mobile wireless telephone unit how wide a "window" of code space (in
6 chips) the mobile unit should search through in order to attempt to synchronize with the
7 PN (pseudo noise) sequence of a given sector. As a general rule, it is desirable to set the
8 window size parameter to be the smallest size that will give an acceptable rate of capture
9 of the PN sequence of the sector.

10 The prior art provides no satisfactory device or process for optimizing choices of
11 window size for the sectors in a network. As with coverage optimization, a network
12 engineer must program the window size parameter at each sector based on his or her best
13 guess as to what should be an optimum value.

14 A related concept in time division type wireless networks (e.g., GSM, TDMA,
15 iDEN) is the "timing advance" parameter. Timing advance is an analogous concept to the
16 window size parameter of CDMA networks, but is directed to finding an appropriate time
17 slot rather than to code synchronization. The prior art does not provide a suitable way to
18 optimize timing advance, either, leaving network engineers to guess their way to an
19 optimum solution. Such a haphazard optimization technique is not an efficient use of the
20 time of highly skilled workers.

21 Thus, what is needed is an effective way to optimize hand off timing parameters
22 for sectors in a wireless network.

23 SUMMARY OF THE INVENTION

24 It is an object of the present invention to provide a labor-saving and time-efficient
25 way to develop optimum coverage-related parameters for sectors of a wireless network.

26 To address the need for a way to develop optimum coverage-related parameters for
27 sectors of a wireless network, the present invention provides a simulation environment.
28 This simulation environment allows a network engineer to vary parameters of a virtual
29 model of the wireless network and observe how the changes affect coverage.

30 It is another object of the present invention to provide algorithms to optimize hand
31 off timing parameters for sectors in a wireless network.

1 To address the need for a way to optimize hand off timing parameters for sectors in
2 a wireless network, the present invention provides an optimization algorithm. The
3 optimization algorithm analyzes measured data regarding network coverage and regional
4 terrain to arrive at a report containing recommended values for window size parameters
5 (code division systems) or timing advance parameters (time division systems). The
6 optimization algorithm analyzes measured data regarding network coverage and regional
7 terrain to arrive at a report containing recommended neighbor lists for each sector.

8 Some of the above objects are obtained by a process of modeling signal strength
9 coverage of a wireless network based on empirical coverage measurements for the
10 network over a region of interest, based on user inputs, and based on terrain data in the
11 region of interest, the network having plural base station antennas. The process includes
12 mapping the empirical coverage measurements onto the terrain data to provide an initial
13 coverage model, and receiving from a user an input for change of a parameter of one of
14 the antennas. The process also includes generating outputs of signal strength at points on
15 the terrain that are affected by the parameter change, and modifying the initial coverage
16 model based on the generated outputs of signal strength to provide a hypothetical coverage
17 model.

18 Some of the above objects are also obtained by a process of generating a neighbor
19 list for a sector-of-interest in a wireless network based on empirical measurements of
20 signal to noise ratio. The process includes calculating a weight for every pair wise
21 combination of the sector-of-interest other network sectors between which a
22 predetermined threshold signal level criteria, T_ADD , is met. The process also includes
23 ordering the calculated weights from largest to smallest, and listing the sectors that meet
24 the T_ADD criteria with respect to the sector-of-interest in rank order corresponding to the
25 ordered calculated weights.

26 Some of the above objects are also obtained by a process of selecting a value of
27 window size for a sector-of-interest in a code division multiple access wireless network.
28 The process includes selecting the earliest arriving multipath signal of all sectors that meet
29 the threshold criteria $E_c/I_o > T_ADD$, wherein T_ADD is a predetermined threshold
30 signal level, and selecting a pair of sectors, ToSector and FromSector, that meet the
31 threshold criteria $E_c/I_o > T_ADD$. The process also includes setting a window size of

1 FromSector = chip delay of ToSector - chip delay of the earliest arriving multipath sector,
2 evaluating whether the window size of FromSector > maximum window size, and in the
3 event that the window size of FromSector is greater than the maximum window size, then
4 set maximum FromSector window size = the window size of FromSector.

5 Some of the above objects are also obtained by a process of generating a value of
6 timing advance for a sector-of-interest in a time division-type wireless network. The
7 process includes selecting a sector, FromSector, with a sufficient Received Signal Strength
8 Indication (RSSI) to serve a call, calculating the distance to FromSector, and setting
9 timing advance of FromSector = one half the distance to FromSector. The process also
10 includes evaluating whether FromSector's timing advance > maximum timing advance,
11 and in the event that FromSector's timing advance is greater than the maximum timing
12 advance, then set maximum FromSector timing advance = FromSector timing advance.

13 BRIEF DESCRIPTION OF THE DRAWINGS

14 Fig. 1 illustrates a high-level flow chart for performing simulation according to an
15 embodiment of the present invention.

16 Fig. 2 illustrates an antenna dialog box according to an embodiment of the present
17 invention.

18 Fig. 3 illustrates a user interface for inputting proposed changes to the network's
19 parameters and displaying simulation results according to an embodiment of the present
20 invention..

21 Fig. 4 illustrates a detail view of the sector select window of Fig. 3.

22 Fig. 5 illustrates a map output display according to an embodiment of the present
23 invention.

24 Fig. 6 illustrates a graph output display according to an embodiment of the present
25 invention.

26 Fig. 7 illustrates an optimized neighbor list generated according to one aspect of
27 the present invention.

28 Fig. 8 illustrates a flowchart for an algorithm to ascertain an appropriate window
29 size for a sector of a CDMA wireless network according to another aspect of the present
30 invention.

1 **Fig. 9** illustrates a flowchart for an algorithm to ascertain an appropriate timing
2 advance for a sector of a time division-type wireless network according to yet another
3 aspect of the present invention.

4 **DETAILED DESCRIPTION OF THE INVENTION**

5 Several types of input information are initially gathered together to create a virtual
6 environment for purposes of simulation of a wireless network. Once the baseline
7 representing the *status quo* is established, a user is able to perform simulations by varying
8 one or more parameters from those that exist in reality. The varied parameters have many
9 affects on performance of the system, and these effects are modeled by the present
10 invention.

11 Referring to **Fig. 1** a high-level flow chart illustrates how simulation is done
12 according to the present invention. Data gathered by a pilot scanner (gathered over days
13 or even weeks of "drive" tests) is used to provide a comprehensive mapping 10 of signal
14 strengths of the sectors of a wireless network in a given region. A user then proposes
15 "what if" changes 20 to the parameters of the network. The pilot scanner data and the
16 proposed "what if" changes are utilized along with data pertaining to antennas used (or
17 that may be used) in the network and three dimensional cartographic data 30 as inputs to
18 an interference engine 40. The interference engine 40 is an algorithm that takes the above-
19 described inputs and generates "what if" outputs of signal strength at points on the terrain
20 that are affected by the proposed "what if" changes. In addition to measured RF data
21 (from drive tests), antenna data, and terrain data, MSC information may also be input.

22 Referring to **Fig. 2**, an antenna dialog box is illustrated. Via the antenna dialog
23 box, antenna data is made available for a user to select as input data. A particular antenna
24 may be selected according to manufacturer and model number 60. Textual information is
25 displayed 80 for the user's consideration, along with graphical displays of an antenna's
26 horizontal gain 50 and vertical gain 70.

27 Referring to **Fig. 3**, a user interface for inputting proposed changes to the
28 network's parameters is illustrated. A "before" plot of E_C/I_0 versus time 110 is displayed
29 adjacent an "after" plot of E_C/I_0 versus time 120. A sector select window for varying
30 parameters of selected sectors 130 is shown along side the signal versus time plots 110,
31 120. The illustrated example shows that sector number 405-2 has been selected and that

one parameter, antenna downtilt, has been changed from 6 degrees to 8 degrees. The signal strength plot for sector 405-2 is highlighted in red in both plots 110, 120. It is clear from inspection of the after plot 120 to the before plot 110 that the proposed antenna downtilt change would have a markedly bad affect on the performance of the sector.

Referring to Fig. 4, a detail of the sector select window 130 is illustrated to provide a detailed view of how various parameters of a selected sector can be varied for simulation. A selection button 405 provides for a user to select any sector in the wireless network for proposed parameter changes.

The antenna azimuth parameter may be changed via the azimuth slide control 425, the actual azimuth value being displayed in brackets 410 and the proposed value 415 being displayed adjacent the azimuth slide control 425. The antenna height parameter may be changed via the height slide control 440, the actual height value (shown in meters) being displayed in brackets 430 and the proposed value 435 being displayed adjacent the height slide control 440. The antenna downtilt parameter may be changed via the downtilt slide control 455, the actual downtilt value being displayed in brackets 445 and the proposed value 450 being displayed adjacent the downtilt slide control 455.

The sector transmission power parameter may be changed via the power delta (i.e., change in power) slide control 465, the original power delta value (zero) is displayed in brackets 460 and the proposed power delta value 470 is displayed adjacent the power delta slide control 465. The user is also free to change the type of antenna being used in the simulation. The actual *status quo* antenna type is displayed in brackets 475 and the selected antenna type is displayed 480 under the "antenna" label. Selections of antenna types are made via the antenna dialog box shown in Fig. 2.

Simulation is performed by numerical calculations performed by an interference engine. The simulation algorithm receives input information in the following form:

- The list of sectors the user wants to change. The simulation needs the old and new power/height/downtilt/azimuth for every sector changed.
- The following measurements at each location where the user wants to simulate the change:
 - $E_c R_c$ — pilot channel power for sector i (units dBm)
 - $(E_c I_o)_i$ — pilot channel signal-to-noise ratio for sector i (units dB)

- I_oW — total received power at this location (units dBm)

The input measurements are typically received in units of dB or dBm, which are nonlinear (logarithmic) units. As most of the calculations disclosed are in linear units, a conversion from logarithmic to linear units would be necessary.

Once the input data has been properly initialized, the following process steps are performed:

- 1) Use pilot channel powers to find X , where X is defined as:

$$X = I_oW / \text{sum}(Ec_iRc)$$

- 2) For each sector whose power or antenna has changed, calculate the new Ec_iRc , which is denoted as Ec_iRc' , after antenna changes:

$$\begin{aligned} Ec_iRc' = & Ec_iRc - \text{oldAntennaGain at LOS path from antenna to this location} \\ & + \text{newAntennaGain at LOS path from antenna to this location} \\ & - \text{oldPower for this sector} \\ & + \text{newPower for this sector} \end{aligned}$$

[NOTE: This calculation is written for dB units instead of linear units]

- 3) Calculate the new total received power, I_oW' , at this location after antenna changes:

$$I_oW' = X \cdot \text{sum}(Ec_iRc')$$

- 4) Find the new Ec/I_o value, for a sector i , at this location after antenna changes:

$$(Ec/I_o)_i' = Ec_iRc' / I_oW'$$

- 5) Perform this for every location that contains measurements from changed sectors.

Once the algorithm has been performed for all changed sectors, the resulting simulation data, Ec_iRc' , $(Ec/I_o)_i'$ and I_oW' , needs to be converted back into logarithmic units (dB or dBm units). These are the results of the simulation that the user will see. The above formulas are preferred simplifications based on a rigorous mathematical derivation.

Simulation outputs are provided as signal strength maps, either two dimensional or virtual reality, as tables of numerical data, and as charts. Referring to Fig. 5, an example, according to an embodiment of the present invention, of a two-dimensional map simulation output is illustrated. Referring to Fig. 6, an example, according to an embodiment of the present invention, of a graph output is illustrated.

The present invention also performs automated optimization of parameters affecting hand off, and generates reports of such automated optimization results.

1 One parameter that is automatically optimized according to the present invention is
2 Window Size in a CDMA system. As a general rule, it is desirable to set the window size
3 parameter to be the smallest size that will give an acceptable rate of capture of the PN
4 sequence of the sector. Since the prior art provides no satisfactory device or process for
5 optimizing choices of window size for the sectors in a network, network engineers have no
6 choice but to program the window size parameter at each sector based on a best guess as to
7 what may be an optimum value.

8 The present invention provides an algorithm that predicts optimum window size
9 based on empirical measurements. The input parameters to the algorithm are E_c/I_0 , pilot
10 channel SNR for a given sector, measured delay time τ from the base location to a given
11 measuring location, and the location information itself. Another factor that affects the
12 algorithm is an assumption that is made as to which particular sector in the network
13 provides the reference time for the hypothetical mobile unit to be handed off.

14 Referring to Fig. 8, a flowchart for an algorithm to ascertain an appropriate
15 window size for a subject sector of a CDMA wireless network is illustrated. The
16 algorithm is applied to empirical drive test data. Multipath signals of all sectors are
17 evaluated to see if they meet the threshold criteria $E_c/I_0 > T_ADD$, and then the earliest
18 arriving is selected 810 therefrom. A pair of sectors, ToSector and FromSector, are
19 selected 820, which meet the threshold criteria $E_c/I_0 > T_ADD$. The window size of the
20 subject sector (i.e., FromSector's window size) is set 830 to a value that is equal to
21 ToSector's chip delay, less the chip delay of the earliest arriving multipath sector. An
22 evaluation is then made 840 as to whether FromSector's window size is greater than the
23 maximum window size of the subject sector. If it is, then the maximum FromSector
24 window size is set 850 to equal to the window size for the subject sector. If it is not, then
25 no action is taken.

26 In either case, an evaluation is then made 860 as to whether this is the last sector
27 measured at a given location. If not, then the algorithm loops back to the step of selecting
28 820 a pair of sectors, ToSector and FromSector. If so, then the algorithm proceeds on to
29 the next measurement location 870 and continues to repeat the algorithm as described
30 above. The algorithm is exhausted 880 when the last measurement location has been
31 exhausted.

1 A related concept in time division type wireless networks (e.g., GSM, TDMA,
2 iDEN) is the "timing advance" parameter. Timing advance is an analogous concept to the
3 window size parameter of CDMA networks, but is directed to finding an appropriate
4 sector signal transmission timing advance rather than to code synchronization.
5 Calculation of optimum timing advance is performed in an analogous manner as to
6 window size.

7 Referring to Fig. 9, a flowchart for an algorithm to ascertain an appropriate timing
8 advance for a sector of a time division type wireless network is illustrated. The algorithm
9 is applied to empirical drive test data. A sector, FromSector is selected 910, with a
10 sufficient Received Signal Strength Indication (RSSI) to serve a call. The distance to
11 FromSector is then calculated 920. The timing advance of the subject sector (i.e.,
12 FromSector's timing advance) is set 930 to a value that is equal to be half of the calculated
13 distance. An evaluation is then made 940 as to whether FromSector's timing advance is
14 greater than the maximum timing advance of the subject sector. If it is, then the maximum
15 FromSector timing advance is set 950 to equal to the timing advance for the subject sector.
16 If it is not, then no action is taken.

17 In either case, an evaluation is then made 960 as to whether this is the last sector
18 measured at a given location. If not, then the algorithm loops back to the step of selecting
19 920 a sector of sufficient RSSI. If so, then the algorithm proceeds on to the next
20 measurement location 970 and continues to repeat the algorithm as described above. The
21 algorithm is exhausted 980 when the last measurement location has been exhausted.

22 Each sector in a wireless network has a neighbor list. Conventionally, the neighbor
23 list was input by a network engineer making a judgement call as to what looked like the
24 best prioritization of which neighboring sectors were most relevant to the subject sector
25 for purposes of making hand offs of calls. For the wireless network to operate effectively,
26 it is important that the prioritization of members of the neighbor list for each sector be
27 accurate.

28 The primary factor in determining ranking of neighbor list members is a quantity
29 called "weight." Weight is calculated, with respect to two neighbor sectors "a" and "b", as
30 follows:
31

$$\text{weight}_{a \rightarrow b} = \sum_{i=1}^n 10^{\{[(E_C/I_0(a,i) - T_ADD) + (E_C/I_0(b,i) - T_ADD)]/10\}}$$

In this equation E_C is the energy per chip in the relevant pilot channel (a or b in this example), I_0 is the total noise power spectral density, E_C/I_0 is the signal-to-noise ratio of each sector at each location, and T_ADD is a predetermined threshold signal level. The value of n represents the number of locations over which summation is to occur.

This weight calculation is calculated for every pair wise combination of sectors between which the T_ADD threshold criteria is met. The input information for this formula is the empirical measurements of E_C/I_0 .

Referring to Fig. 7, a table is shown that comprises an output report according to the automatic optimization aspect of the present invention. The Sector Name column lists, in descending rank order, the ten sectors that make up the Neighbor List for sector number 161-3. The SRCH_WIN_N column lists the optimized search window sizes for the sectors on the Neighbor List.

Additionally, the present invention generates a Neighbor Discrepancy List, which is a comparison of the Neighbor List before optimization and the Neighbor List after optimization.

Although the present invention has been described in terms of preferred embodiments, various modifications and variations may be made without departing from the scope of the invention, as will be understood by those of skill in the art. The present invention is limited only by the appended claims.

WHAT IS CLAIMED IS:

1 1. A process of modeling signal strength coverage of a wireless network based on
2 empirical coverage measurements for the network over a region of interest, based on user
3 inputs, and based on terrain data in the region of interest, the network having plural base
4 station antennas, the process comprising:

5 mapping the empirical coverage measurements onto the terrain data to provide an
6 initial coverage model;

7 receiving from a user an input for change of a parameter of one of the antennas;

8 generating outputs of signal strength at points on the terrain that are affected by the
9 parameter change; and

10 modifying the initial coverage model based on the generated outputs of signal
11 strength to provide a hypothetical coverage model.

1 2. The process of claim 1, wherein the parameter is chosen from the group
2 consisting of: antenna height, antenna tilt angle, antenna type, antenna azimuth, and
3 transmitted signal power at the antenna.

1 3. The process of claim 1, further comprising:
2 providing a visual representation of signal strength coverage according to the
3 initial coverage model.

1 4. The process of claim 1, further comprising:
2 providing a visual representation of signal strength coverage according to the
3 hypothetical coverage model.

1 5. The process of claim 1, further comprising:
2 providing a comparative visual representation of signal strength coverage
3 according to superposition of the initial coverage model with the hypothetical coverage
4 model.

1 6. A process of generating a neighbor list for a sector-of-interest in a wireless
2 network based on empirical measurements of signal to noise ratio, the process comprising:

calculating a weight for every pair wise combination of the sector-of-interest other network sectors between which a predetermined threshold signal level criteria, T_ADD, is met;

ordering the calculated weights from largest to smallest; and
listing the sectors that meet the T_ADD criteria with respect to the sector-of-interest in rank order corresponding to the ordered calculated weights.

7. The process of claim 6, wherein weight is calculated, with respect to two neighbor sectors a and b, as follows:

$$\text{weight}_{a \rightarrow b} = \sum_{i=1}^n 10^{\{[(E_c/I_0(a,i) - T_ADD) + (E_c/I_0(b,i) - T_ADD)]/10\}}$$

wherein E_c/I_0 is the signal-to-noise ratio of each sector at each location, and the value of n represents the number of locations over which summation is to occur.

8. A process of selecting a value of window size for a sector-of-interest in a code division multiple access wireless network, the process comprising:

select the earliest arriving multipath signal of all sectors that meet the threshold criteria $E_c/I_0 > T_ADD$, wherein T_ADD is a predetermined threshold signal level;

select a pair of sectors, ToSector and FromSector, that meet the threshold criteria $E_c/I_0 > T_ADD$;

set a window size of FromSector = chip delay of ToSector - chip delay of the earliest arriving multipath sector;

evaluate whether the window size of FromSector > maximum window size; and

in the event that the window size of FromSector is greater than the maximum window size, then set maximum FromSector window size = the window size of FromSector.

9. A process of generating a value of timing advance for a sector-of-interest in a time division-type wireless network, the process comprising:

select a sector, FromSector, with a sufficient Received Signal Strength Indication (RSSI) to serve a call;

calculate the distance to FromSector;

6 set timing advance of FromSector = one half the distance to FromSector;
7 evaluate whether FromSector's timing advance > maximum timing advance; and
8 in the event that FromSector's timing advance is greater than the maximum timing
9 advance, then set maximum FromSector timing advance = FromSector timing advance.

1 10. A computer program product for enabling a computer to model signal strength
2 coverage of a wireless network based on empirical coverage measurements for the
3 network over a region of interest, based on user inputs, and based on terrain data in the
4 region of interest, the network having plural base station antennas, the computer program
5 product comprising:

6 software instructions for enabling the computer to perform predetermined operations, and
7 a computer readable medium embodying the software instructions;

8 the predetermined operations comprising:

9 mapping the empirical coverage measurements onto the terrain data to provide an
10 initial coverage model;

11 receiving from a user an input for change of a parameter of one of the antennas;

12 generating outputs of signal strength at points on the terrain that are affected by the
13 parameter change; and

14 modifying the initial coverage model based on the generated outputs of signal strength
15 to provide a hypothetical coverage model.

1 11. A computer program product for enabling a computer to generate a neighbor
2 list for a sector-of-interest in a wireless network based on empirical measurements of
3 signal to noise ratio, the computer program product comprising:

4 software instructions for enabling the computer to perform predetermined operations, and
5 a computer readable medium embodying the software instructions;

6 the predetermined operations comprising:

7 calculating a weight for every pair wise combination of the sector-of-interest other
8 network sectors between which a predetermined threshold signal level
9 criteria, T_ADD, is met;

10 ordering the calculated weights from largest to smallest; and

11 listing the sectors that meet the T_ADD criteria with respect to the sector-of-
12 interest in rank order corresponding to the ordered calculated weights.

1 12. A computer program product for enabling a computer to select a value of
2 window size for a sector-of-interest in a code division multiple access wireless network,
3 the computer program product comprising:
4 software instructions for enabling the computer to perform predetermined operations, and
5 a computer readable medium embodying the software instructions;
6 the predetermined operations comprising:

7 select the earliest arriving multipath signal of all sectors that meet the threshold
8 criteria $E_c/I_o > T_ADD$, wherein T_ADD is a predetermined threshold
9 signal level;

10 select a pair of sectors, ToSector and FromSector, that meet the threshold criteria
11 $E_c/I_o > T_ADD$;

12 set a window size of FromSector = chip delay of ToSector - chip delay of the
13 earliest arriving multipath sector;

14 evaluate whether the window size of FromSector > maximum window size; and
15 in the event that the window size of FromSector is greater than the maximum
16 window size, then set maximum FromSector window size = the window
17 size of FromSector.

1 13. A computer program product for enabling a computer to generate a value of
2 timing advance for a sector-of-interest in a time division-type wireless network, the
3 computer program product comprising:
4 software instructions for enabling the computer to perform predetermined operations, and
5 a computer readable medium embodying the software instructions;
6 the predetermined operations comprising:

7 select a sector, FromSector, with a sufficient Received Signal Strength Indication
8 (RSSI) to serve a call;

9 calculate the distance to FromSector;

10 set timing advance of FromSector = one half the distance to FromSector;

11 evaluate whether FromSector's timing advance > maximum timing advance; and

12 in the event that FromSector's timing advance is greater than the maximum timing
13 advance, then set maximum FromSector timing advance = FromSector
14 timing advance.

1 14. A computer system adapted to model signal strength coverage of a wireless
2 network based on empirical coverage measurements for the network over a region of
3 interest, based on user inputs, and based on terrain data in the region of interest, the
4 network having plural base station antennas, comprising:
5 a processor, and
6 a memory including software instructions adapted to enable the computer system
7 to perform operations comprising:
8 mapping the empirical coverage measurements onto the terrain data to provide
9 an initial coverage model;
10 receiving from a user an input for change of a parameter of one of the antennas;
11 generating outputs of signal strength at points on the terrain that are affected by
12 the parameter change; and
13 modifying the initial coverage model based on the generated outputs of signal
14 strength to provide a hypothetical coverage model.

1 15. A computer system adapted to generate a neighbor list for a sector-of-interest
2 in a wireless network based on empirical measurements of signal to noise ratio,
3 comprising:
4 a processor, and
5 a memory including software instructions adapted to enable the computer system
6 to perform operations comprising:
7 calculating a weight for every pair wise combination of the sector-of-interest
8 other network sectors between which a predetermined threshold signal level
9 criteria, T_ADD, is met;
10 ordering the calculated weights from largest to smallest; and
11 listing the sectors that meet the T_ADD criteria with respect to the sector-of-
12 interest in rank order corresponding to the ordered calculated weights.

1 16. A computer system adapted to select a value of window size for a sector-of-
2 interest in a code division multiple access wireless network, comprising:

3 a processor, and

4 a memory including software instructions adapted to enable the computer system
5 to perform operations comprising:

6 select the earliest arriving multipath signal of all sectors that meet the threshold
7 criteria $E_c/I_o > T_ADD$, wherein T_ADD is a predetermined threshold
8 signal level;

9 select a pair of sectors, ToSector and FromSector, that meet the threshold
10 criteria $E_c/I_o > T_ADD$;

11 set a window size of FromSector = chip delay of ToSector - chip delay of the
12 earliest arriving multipath sector;

13 evaluate whether the window size of FromSector > maximum window size;
14 and

15 in the event that the window size of FromSector is greater than the maximum
16 window size, then set maximum FromSector window size = the window
17 size of FromSector.

1 17. A computer system adapted to generate a value of timing advance for a sector-
2 of-interest in a time division-type wireless network, comprising:

3 a processor, and

4 a memory including software instructions adapted to enable the computer system
5 to perform operations comprising:

6 select a sector, FromSector, with a sufficient Received Signal Strength
7 Indication (RSSI) to serve a call;

8 calculate the distance to FromSector;

9 set timing advance of FromSector = one half the distance to FromSector;

10 evaluate whether FromSector's timing advance > maximum timing advance;

11 and

12 in the event that FromSector's timing advance is greater than the maximum
13 timing advance, then set maximum FromSector timing advance =
14 FromSector timing advance.

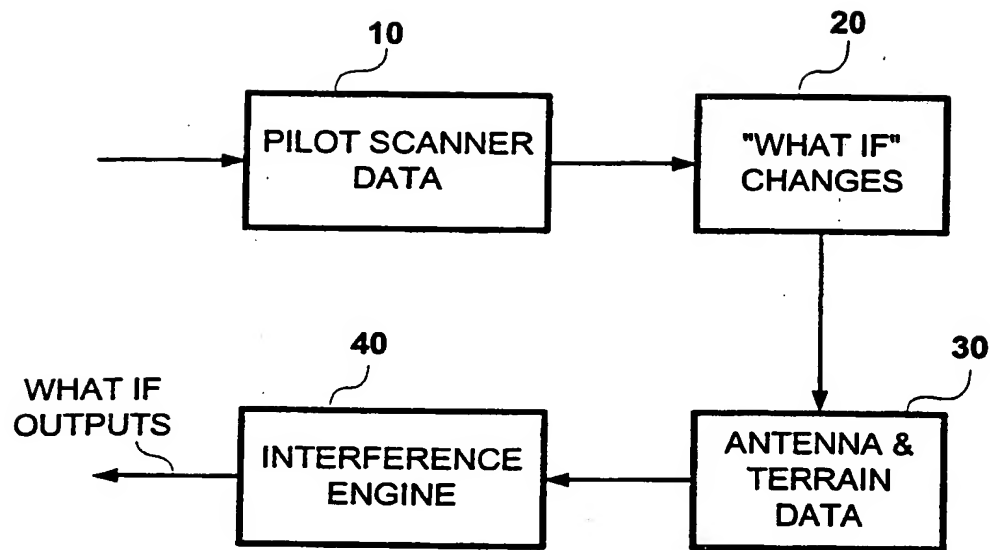
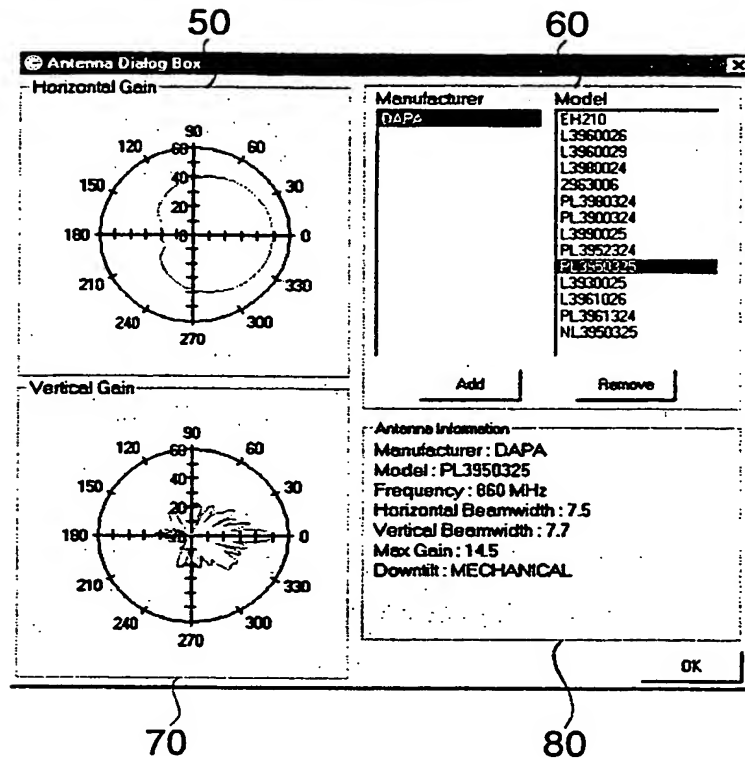


FIG. 1

FIG. 2



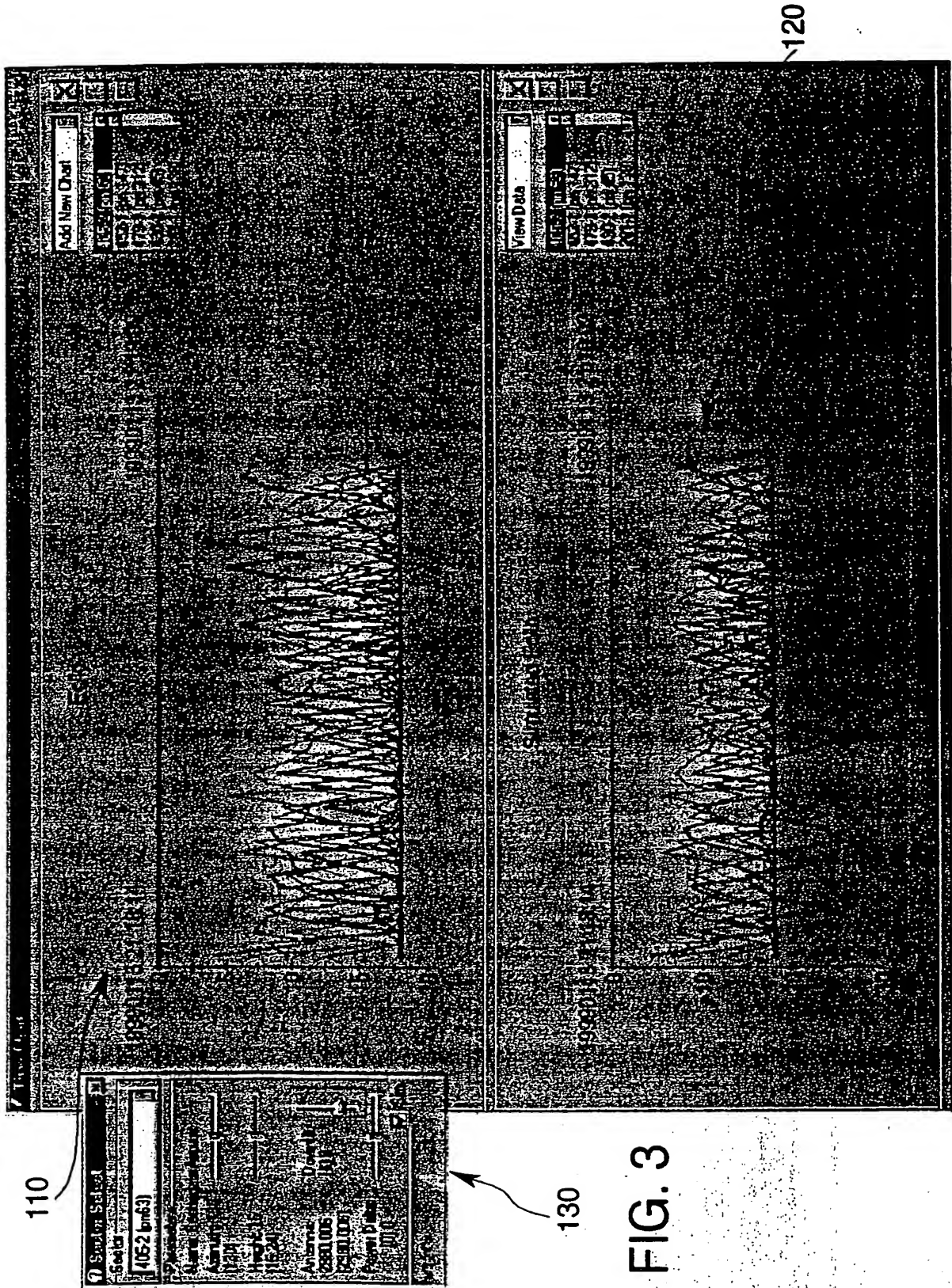


FIG. 3

FIG. 4

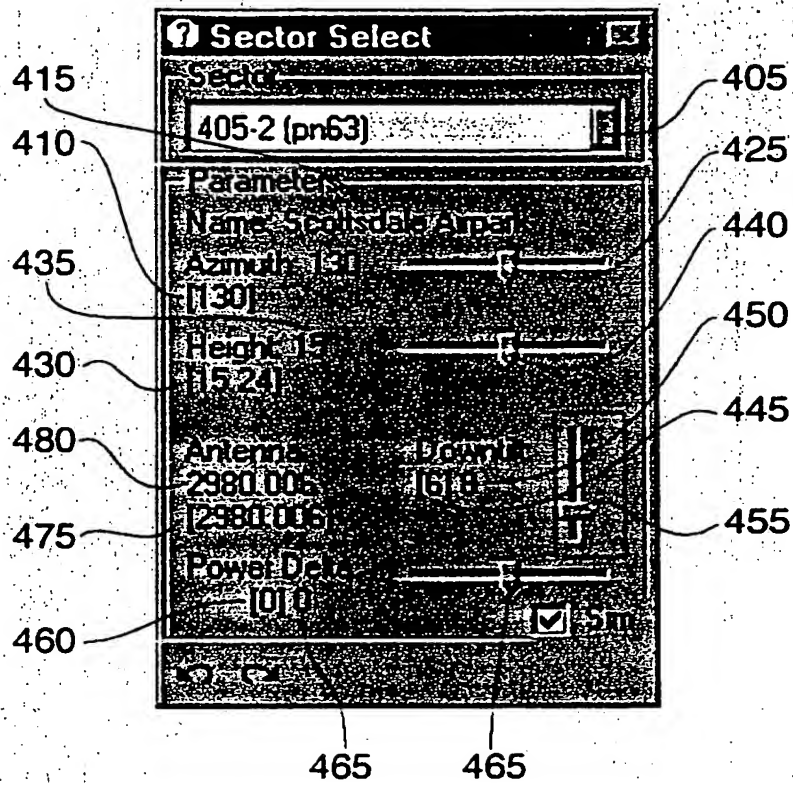


FIG. 5

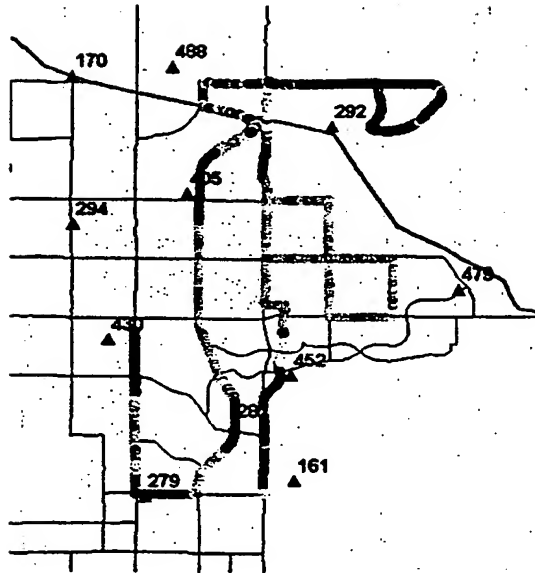
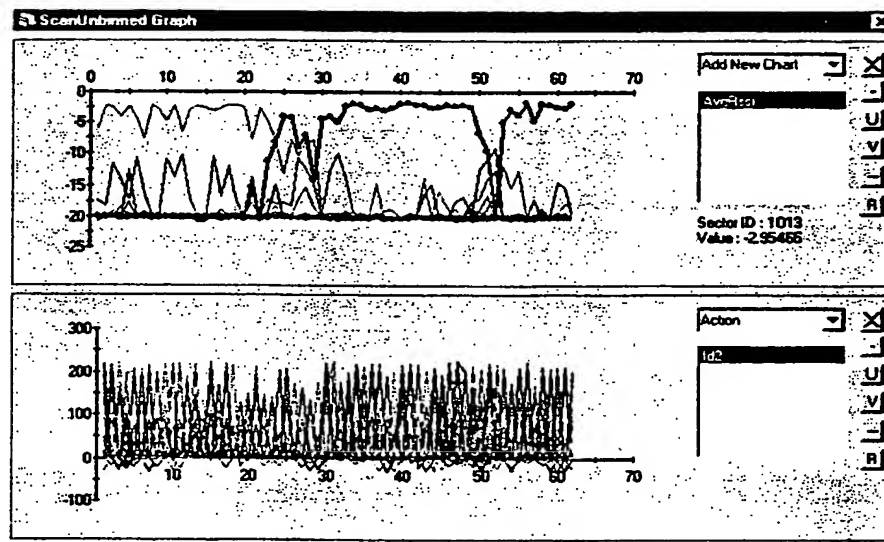


FIG. 6



161-3 (pn 285)

	Sector Name	Weight	Number of Points	Chip Offset	SRCH_WIN_N
1	161-1 (pn 282)	65.17	174	5.8	4
2	279-1 (pn 273)	1.521	7	9.3	5
3	279-2 (pn 279)	0.666	2	8.8	5
4	281-2 (pn 144)	6.102	32	5.8	4
5	281-3 (pn 141)	6.272	23	0.9	0
6	413-1 (pn 210)	1.430	7	12.2	6
7	452-2 (pn 153)	8.626	40	11.7	6
8	452-3 (pn 150)	37.16	132	11.7	6
9	478-1 (pn 93)	0.495	3	19.1	7
10	479-3 (pn 312)	0.353	2	26.6	8

FIG. 7

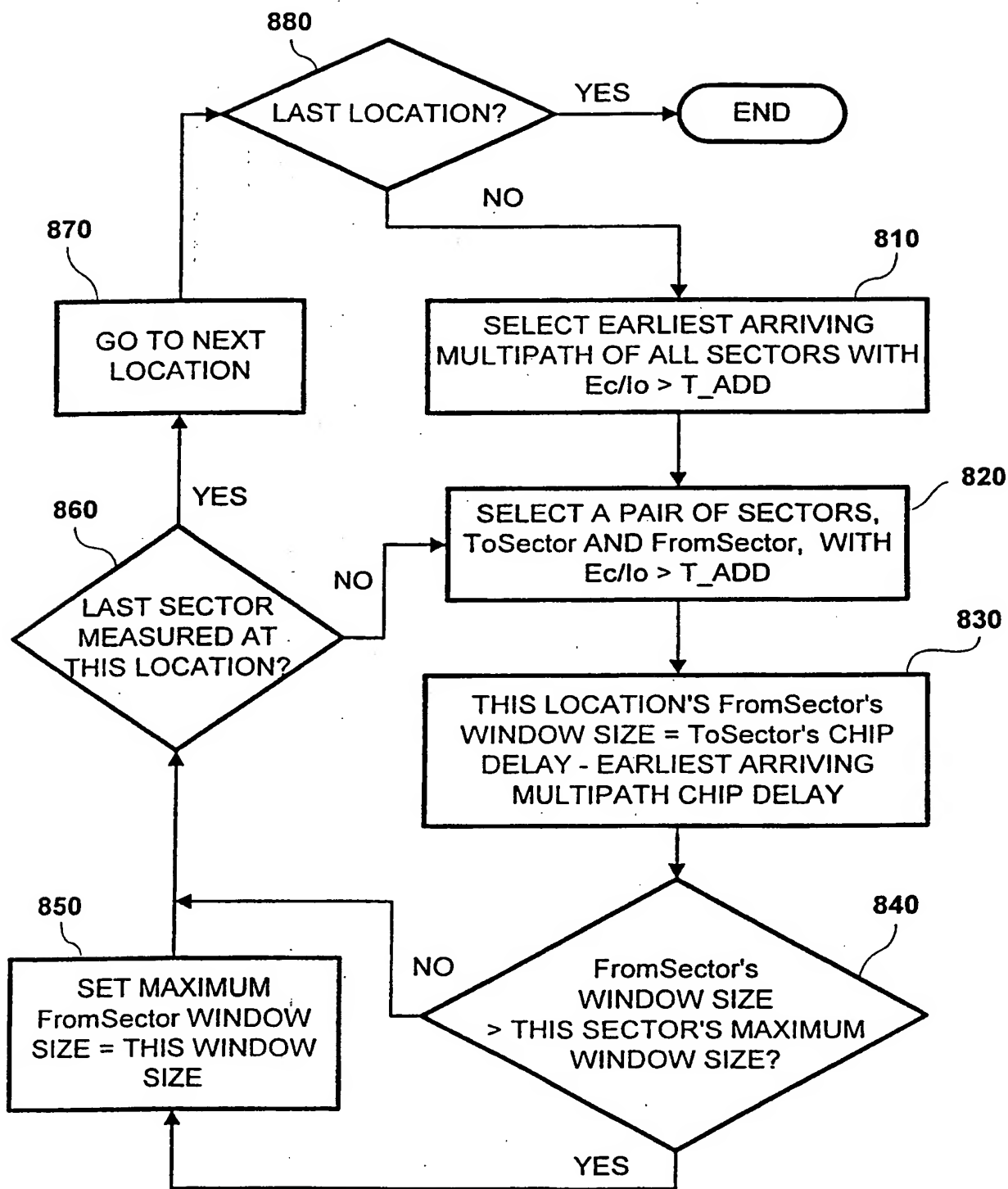


FIG. 8

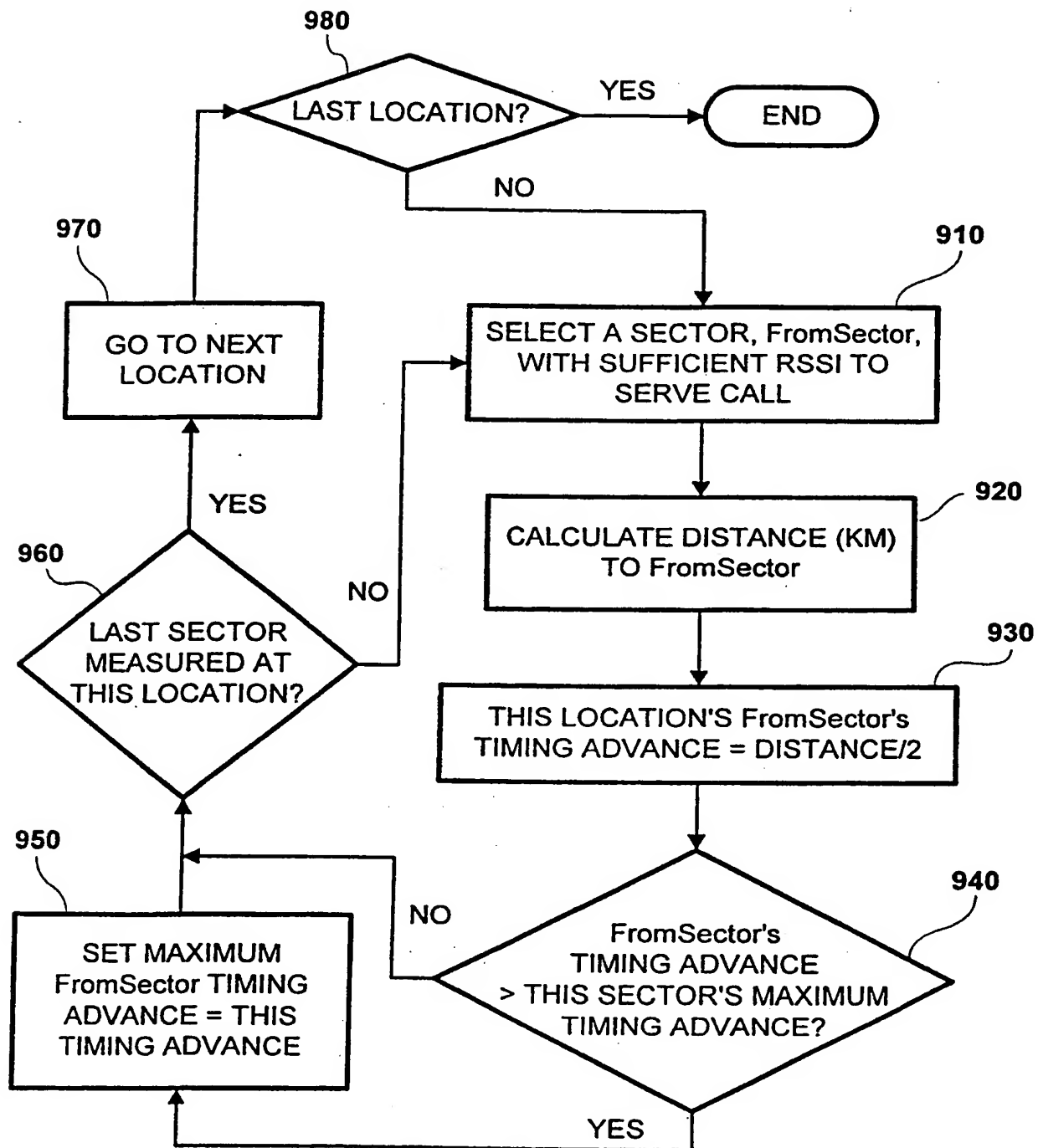


FIG. 9

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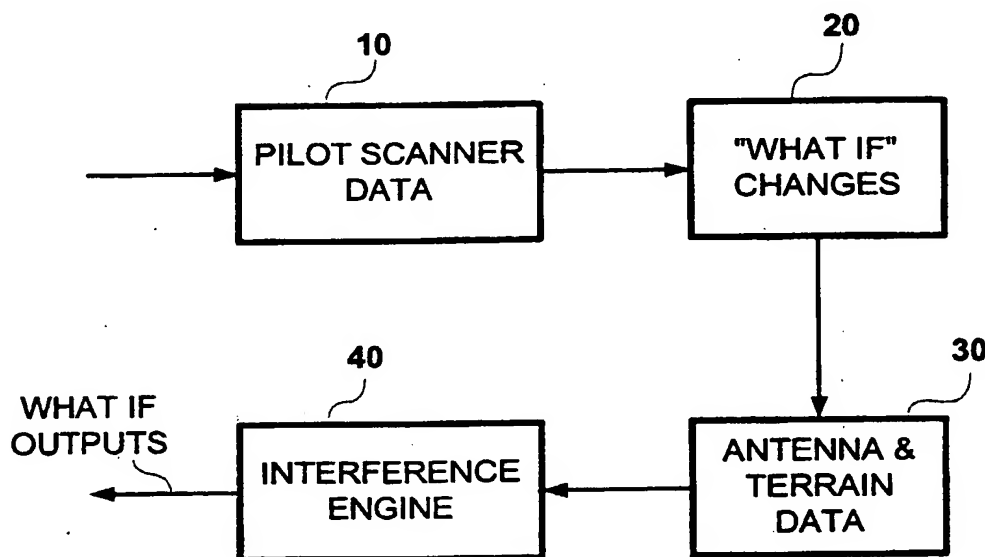
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60/149,888 **19 August 1999 (19.08.1999)** **US**
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(54) Title: **WIRELESS TELEPHONE NETWORK OPTIMIZATION**



(57) Abstract: A wireless network can be easily optimized utilizing processes according to the present invention. A simulation environment allows a network engineer to vary parameters (e.g., antenna height, tilt, and power) of a virtual model of the wireless network and observe how the changes affect coverage. Algorithms also enable hand off timing parameters for sectors in a wireless network to be optimized. One algorithm analyzes measured data regarding network coverage and regional terrain to arrive at a report containing recommended values for window size parameters (code division systems) or timing advance parameters (time division systems). Another algorithm analyzes measured data regarding network coverage to arrive at a report containing recommended neighbour list for each sector in the network.

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INTERNATIONAL SEARCH REPORT

In ternational Application No

PCT/US 00/22873

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 H04Q7/36

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 H04Q H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	WO 97 41652 A (MOTOROLA INC) 6 November 1997 (1997-11-06) page 5, line 33 -page 6, line 8 -----	

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 00/22873

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☒ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
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- ☐ The additional search fees were accompanied by the applicant's protest.
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FURTHER INFORMATION CONTINUED FROM PCT/SA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. Claims: 1-5, 10, 14

Simulation and graphical representation of the effect of an antenna parameter modification onto the coverage of an existing network

2. Claims: 6, 7, 11, 15

Neighbor list determination

3. Claims: 8, 12, 16

CDMA window size determination

4. Claims: 9, 13, 17

Timing advance determination

INTERNATIONAL SEARCH REPORT

Information on patent family members

In. tional Application No

PCT/US 00/22873

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
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